Smart cities research in Portugal and Spain

An exploratory biliometric analysis

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Abstract — **In this paper it is presented a bibliometric analysis on smart cities research in Portugal and Spain performed using the Scopus® database as a source. Number of articles, citations to those articles, types of sources, most productive and impacting authors and institutions, most cited articles and more relevant subject areas are analyzed and discussed. It is concluded that there is a significant gap between Portugal and Spain in terms of the impact of the research produced, partially explained with the subjects addressed and type of publications used. The results presented here can be of use to researchers and policy makers in the field of Smart Cities' research mainly as a basis for benchmarking.**

Keywords – smart cities; bibliometrics; portugal; spain.

I. INTRODUCTION

There are many definitions of what a 'smart city' is. In the 1990s, when the expression was first used, the focus was "on the significance of new ICT with regard to modern infrastructures within cities" [1] but it then evolved to gain a more comprehensive meaning, involving other aspects of urban development. In an example, smart cities "will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone" [2]. In a different example, a city is 'smart' "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" [3]. In this latter and more comprehensive view of what a 'smart city' is, various dimensions or development axes can be identified: smart economy; smart mobility; smart environment; smart people; smart living; smart governance [3].

Regardless of the concept of a 'smart city' that is used - more focused on technologies or in its urban or social implications - it is undeniable that Digital Cities have become a hot research topic for academics in the last years. Naturally, given the different views on the subject, the theme is studied in the scope of various disciplines and several research perspectives and research methodologies coexist. This in itself justifies the interest in better understanding what is being researched, how, by whom and where.

The main objective of the exploratory study presented in this article was precisely to contribute to establish the current state of affairs concerning Smart Cities research in Portugal and Spain and comparing the scientific production and its achieved impact for both countries. Complementarily, it was envisioned to better understand what the main impact drivers of the produced research are. The motivation was to establish a benchmark basis for researchers and research police makers in the Region.

Bibliometric analysis was selected as the methodology to support this study. Although having important limitations, bibliometric methods have the advantage of allowing general conclusion about research production and impact on specific areas of knowledge without the burden of a thorough bibliographical review.

No previous bibliometric analysis or bibliographic reviews on the topic of Smart Cities in Portugal or Spain were identified in the literature.

The remaining of this article is organized as follows: in Section II the methods are described, in Section III the results are presented and discussed and, finally, in Section IV the conclusions and the future work are addressed.

II. METHODS

The bibliometric analysis was based in data retrieved from the Scopus® database. All documents published until the end of 2017 by authors affiliated to Portuguese or Spanish institutions with the expressions 'smart city' or 'smart cities', in their titles, abstracts or keywords where retrieved (see expression 1). The methodology is based on the one used by Dias for his study on e-government research in Portugal [4]. Data was retrieved on January 13th 2018.

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TITLE-ABS-KEY({smart city})
OR TITLE-ABS-KEY({smart cities})
AND AFFILCOUNTRY(portugal)                    (1)
OR AFFILCOUNTRY(spain)
AND PUBYEAR > 2007
AND PUBYEAR < 2018
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A total of 728 documents were retrieved. Those included 405 conference papers, 283 articles, 15 book chapters, 12 reviews, seven editorials, three books and three articles in press. Concerning language, 695 documents were written in English, 35 in Spanish and three in Portuguese. No documents prior to 2011 were retrieved.

The data was then analyzed using the Scopus® web interface to produce information concerning the total numbers of documents and citations and their evolution, types of publication sources, most productive authors and institutions, most cited articles, and main subject areas. Only citations obtained until the end of 2017 were computed.

For subject areas analysis, the original Scopus® subject areas were grouped as represented in Table I.

TABLE I. SUBJECT AREAS GROUPING

subject areas grouping	original Scopus® subject areas
computer science	computer science
engineering	engineering; chemical engineering
sciences	mathematics; physics and astronomy; energy; biochemestry, genetics amd molecular biology; chemistry; enviromental sciences; materials sciences; earth and planetary sciences; agricultural and biological sciences
social sciences	social sciences; business, management and accounting; economics, econometrics and finance
other	medicine; health professions; neuroscience; arts and humanities; psychology; multidisciplinary

III. RESULTS AND DISCUSSION

The results of the bibliometric analysis are presented and discussed in the following six subsections, each one dedicated to a different perspective of analysis.

A. Number of documents and citations

Table II presents the global figures for documents published and citations received for each of the countries and for the two countries as a whole. These figures are complemented with the graphs in Figures 1 and 2 that depict the evolution of documents published and citation received, respectively, for Portugal and Spain, between 2011 and 2017.

TABLE II. ARTICLES AND CITATIONS

global metrics	territories		
	Portugal	*Spain*	*Portugal & Spain*
total documents	149	592	872
total citations	454	3 197	3 634
average citations	3.05	5.40	4.17

As can be observed, Spanish institutions have published about four times more documents than Portuguese institutions, which is below the relative proportion of the countries number of inhabitants, but Spain affiliated publications have a significantly higher average citation. The number of publications and citations received has grown continuously for both countries since 2011.

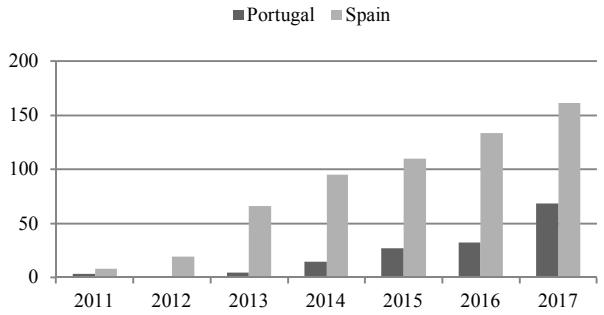

Figure 1. Evolution of the number of documents published between 2011 and 2017.

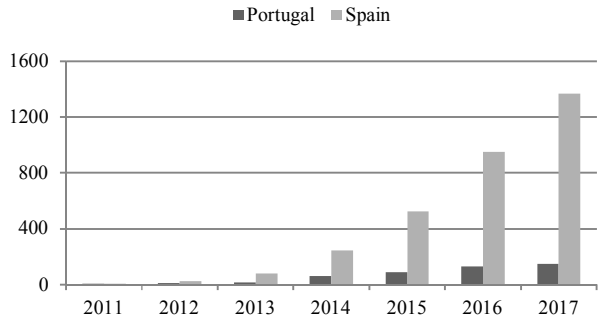

Figure 2. Evolution of the number of citations received between 2011 and 2017 for documents published within the time window.

B. Types of sources

Tables III and IV present the document counts by type of publication source, the weight of each type of publication source in the total number of documents, and the total number of citations received and the average citations per document for each source type, for Portugal and Spain, respectively.

TABLE III. TYPES OF SOURCES FOR PORTUGAL

Portugal	source type metrics			
	documents	*weight*	*citations*	*average citations*
conference proceedings	86	58%	78	0.91
journals	38	26%	99	2.61
other	25	17%	277	11.08

Comparing the two tables, it is evident that Spain has a higher percentage of journal articles than Portugal and that it has higher average citations per document both for journal articles and conference proceedings. These are typical

indicators of better quality and higher impact of the publications. The atypically high citation average that Portugal displays for the 'other' sources has no special meaning since it results from the contribution of a single article published in a book series [5]. Alone it received 262 of the 277 citations registered.

TABLE IV. TYPES OF SOURCES FOR SPAIN

Spain	source type metrics			
	documents	*source weight*	*citations*	*average citations*
conference proceedings	225	38%	773	2.62
journals	252	43%	2113	6.63
other	115	19%	311	4.60

C. Most productive authors

Table V lists the most productive authors affiliated to Portuguese institutions and their main bibliometric indicators. From the Table, it is evident that there are no individual authors in Portugal that simultaneously exhibit good production and impact figures.

The same is not true for Spain, as can be seen in Table VI. Indeed, there are several productive authors affiliated to Spanish institutions that simultaneously exhibit very good average citations and *h*-index.

TABLE V. MOST PRODUCTIVE AUTHORS FOR PORTUGAL

Portugal	author metrics				
	doc.	*cit.*	*av. cit.*	*h-index*	*affiliation*
Pitarma, R.	9	22	2.44	3	Inst. Polit. da Guarda
Marques, G.	5	12	2.40	2	Inst. Polit. da Guarda
Caetano, F.	5	11	2.20	2	Inst. Polit. da Guarda
Rodriguez, J.	5	9	1.80	1	Inst. de Telecom.
Bhattacharya, D.	4	8	2.00	1	Univ. do Minho
Monteiro, E.	4	8	2.00	1	Univ. de Coimbra
Anaclide, C.	5	3	0.60	1	Univ. do Minho
Novais, P.	5	3	0.60	1	Univ. do Minho
Bernardes, M.B.	4	0	0.00	0	Univ. do Minho
Ferreira, J.	4	0	0.00	0	Univ. de Aveiro

Another interesting aspect is that both in Portugal and in Spain there are teams that cooperate within the same institution. Indeed, the listed authors from *Instituto Politécnico. da Guarda* have coauthored several documents and the same is true for the authors listed from *Universidade do Minho*, in Portugal, and from *Universidad de Cantabria* and from *Universidad de Malaga*, in Spain. However, it is also visible that these different teams have very different impacts on the field, with special emphasis on the team from the *Universidad de Cantabria*.

TABLE VI. MOST PRODUCTIVE AUTHORS FOR SPAIN

Spain	author metrics				
	art.	*cit.*	*av. cit.*	*h-index*	*affiliation*
Galache, J.A.	14	396	28.29	8	Univ. de Cantabria
Skarmeta, A.F.	14	190	13.57	8	Univ. de Murcia
Muñoz, L.	20	323	16.15	7	Univ. de Cantabria
Solanas, A.	15	239	15.93	6	Univ. Rovira i Virgili
Santana, J.R.	9	172	19.11	5	Univ. de Cantabria
Sotres, P.	8	171	21.38	5	Univ. de Cantabria
Falcone, F.	12	181	15.08	4	Univ. Publica de Navarra
Marsal-Llacuna, M.L.	8	57	7.13	4	Intelligent'Er Research Ass.
Alba E.	19	35	1.84	4	Univ. de Malaga
Stolfi, D.H.	9	28	3.11	4	Univ. de Malaga

D. Most productive institutions

Tables VII and VIII list the most productive institutions in Portugal and Spain, respectively, including their aggregated bibliometric indicators.

TABLE VII. MOST PRODUCTIVE INSTITUIONS IN PORTGUGAL

Portugal	institution metrics			
	doc.	*citations*	*average citations*	*h-index*
Inst. de Telecomunicações	24	43	1.79	4
Univ. do Minho	24	32	1.33	4
Univ. de Aveiro	16	18	1.13	3
Univ. da Beira Interior	12	39	3.25	3
Inst. Polit. da Guarda	9	23	2.56	3
Univ. Nova de Lisboa	19	15	0.79	2
Univ. de Lisboa	16	14	0.88	2
Univ.do Porto	11	13	1.18	2
Univ. de Trás-os-Montes e Alto Douro	6	9	1.50	2
Univ. de Coimbra	10	11	1.10	1

As has been observed in the previous subsections, also here it is possible to verify that there is an important gap between the production and impact of research undertaken in Portugal and Spain in the field of Smart Cities: the aggregated bibliometric indicators for the Spanish institutions are significantly better than for the Portuguese institutions.

TABLE VIII. MOST PRODUCTIVE INSTITUIONS IN SPAIN

Spain	institution metrics			
	doc.	*citations*	*average citations*	*h-index*
Univ. Polit. de Catalunya	47	321	6.83	9
Univ. de Catabria	33	451	13.67	8
Univ. de Murcia	20	206	10.30	8
Univ. Rovira i Virgili	21	287	13.67	7
Univ. Pub. de Navarra	19	201	10.58	5
Univ. de Malaga	31	57	1.84	5
Univ. de Deusto	22	59	2.68	4
Univ. Polit. de Madrid	34	161	4.74	3
Univ. de Granada	22	48	2.18	3
Univ. Carlos III de Madrid	17	32	1.88	3

As one evidence, the *Instituto de Telecomunicações*, a Portuguese research center to each researchers from several Portuguese universities are affiliated, is only the eighth more impacting institution (higher *h*-index, higher citations) in the Iberian countries and in the field of Smart Cities.

E. Most cited articles

Tables IX and X list the most cited documents authored by authors affiliated to Portuguese and Spanish institutions, respectively. Number of citations received, type of document and the main approach/subject address in the document are also presented.

TABLE IX. MOST CITED PORTUGUESE DOCUMENTS

Portugal	document characterization		
	cit.	*type*	*approach*
Schaffers [5]	262	book series.	policy/concept
Kumar et al. [6]	16	journal	new technology
Zhu, et al. [7]	12	journal	new technology
Niforatos et al. [8]	9	conference	application
Marques & Pitarma [9]	8	journal	application
Simões & Estanqueiro [10]	8	journal	new technology
Oliveira & Campolargo [11]	8	conference	policy/concept
Palma et al. [12]	8	conference	application

TABLE X. MOST CITED SPANISH ARTICLES

Portugal	document characterization		
	cit.	*type*	*approach*
Zanella et al [13]	629	journal	smart city case
Solanas et al. [14]	128	journal	policy/concept
Sanchez et al. [15]	119	journal	smart city case
Bakici et al. [16]	90	journal	smart city case
Hernández-Muñoz et al. [17]	88	book series	policy/concept
Sanchez et al. [18]	62	cconference	smart city case
Martinez-Balleste [19]	61	journal	policy/concept
Dobre and Xhafa [20]	52	journal	new technology
Hess et al. [21]	46	conference	application
Barba, et al. [22]	46	conference	new technology

Naturally, these results mirror the previous identified gap between research on Smart Cities in Portugal and Spain. But they also shed some light on why it is happening so. From the tables it seems evident that the most cited documents are typically articles published in journals or book series that address policy or concept issues or address concrete smart city cases (Padova [13], Santander [15,18] and Barcelona [16]), in detriment of conference papers that address technological issues or concrete applications cases, and the latter are much more common in the list of more cited Portuguese documents than in the Spanish list. It is also noteworthy the absence of 'smart city' cases in the list for Portugal. Contrary, the effect of the existence of such cases in Spain is evident [15,16,18].

F. Main subect areas

Tables XI and XII show the classification of documents in different aggregated subject areas, for Portugal and Spain, respectively. Note that one document might be classified in more than one subject area according to the subject classifications of the publication source. The number of documents published, their weight in the total number of publications, the number of citations received and the average number of citations per document for each aggregated subject area are presented.

From the tables it is observable that the majority of documents are published in sources classified as Computer Science, followed by Sciences, Engineering and Social Sciences. Average citations for Computer Science, Sciences and Social Sciences are typically higher than for Engineering, which is consistent with the lower impact of documents that address technological or concrete application cases, as identified in the precious section.

TABLE XI. SUBJECT AREAS FOR PORTUGAL

Portugal	subject area metrics			
	documents	*weight*	*citations*	*average citations*
Computer Science	109	73%	379	3.48
Sciences	88	59%	400	4.55
Engineering	48	32%	58	1.21
Social Sciences	29	19%	20	0.69
Other	3	2%	10	3.33

TABLE XII. SUBJECT AREAS FOR SPAIN

Spain	subject area metrics			
	documents	*weight*	*citations*	*average citations*
Computer Science	382	65%	2314	6.06
Sciences	234	40%	1477	6.31
Engineering	219	37%	947	4.32
Social Sciences	93	16%	429	4.61
Other	17	3%	101	5.94

It is worth mentioning that when compared to Spain Portugal has higher weights for Computer Science and Sciences in detriment of Engineering and Social Sciences. Also, Portugal exhibits atypically low average citations figures for these two least represented subject areas.

IV. CONCLUSIONS AND FUTURE WORK

When compared to Portugal, Spain has very good bibliometric indicators in the field of Smart Cities. In the last seven years its researchers published about four times more documents than the Portuguese counterparts, with a higher percentage of journal articles and with about seven times more citations. Among the ten most productive Iberian authors there are nine authors affiliated to Spanish institutions, and among the ten most productive Iberian institutions there are nine Spanish universities. Also, the most productive Spanish authors and institutions tend to receive more citations, have higher citation averages and higher *h*-indexes. Also, the citation average for documents published by authors affiliated to Spanish institutions is higher than for the Portuguese counterparts in all studied subject areas: computer science, sciences, engineering, and social sciences.

To what concerns Portugal, the panorama is naturally the opposite. If it could be expected that the number of published documents would be lower than that calculated for Spain, given the difference in size between the two countries, the same is no longer the case for the other indicators. Indeed, the country dimension would not prevent the existence of authors or institutions in Portugal with bibliometric indicators perfectly comparable to the Spaniards, as is the case in other areas. So, it can be concluded that a significant gap exists between the volume and impact of the research produced in Portugal and Spain in the field of Smart Cities.

One of the reasons that contributes to this gap is the fact that Spanish authors tend to publish more in journals and book series which have typically higher citation rates, while the Portuguese publish more in conference proceedings. Another reason is that Spanish authors have published more documents addressing policy and conceptual issues and addressing specific smart cities' cases that also assure higher citation rates. In this respect it is interesting to note that three out of the five more cited articles relate to the Santander and Barcelona cases, which are two well-known success cases of Spanish 'smart cities'.

There is a limit for what can be achieved with a bibliometric analysis. A deeper view of the development of the field in the Iberian countries would always require the use of other methodologies, such as content analysis or case study. Nonetheless, there are two additional aspects that can be developed in the scope of a bibliometric study and constitute the future work of the presented investigation. Those are the comparison of global indicators of Spain and Portugal with other European and non-European countries, and the international cooperation between Portugal and Spain and between each one of them and third countries, and the importance of those collaborations to the development of research on Smart Cities in the Iberian countries.

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